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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 239.

B. T. GALLOWAY, *Chief of Bureau.*

COST AND METHODS OF CLEARING LAND IN WESTERN WASHINGTON.

BY

HARRY THOMPSON,

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 4, 1911.

Sir: I have the honor to transmit herewith a manuscript entitled "Cost and Methods of Clearing Land in Western Washington," prepared by Mr. Harry Thompson, of the Office of Farm Management, and to recommend its publication as a bulletin of the Bureau of Plant Industry.

Some of the data in this manuscript relating to the use of explosives in removing stumps are taken from a report made by Mr. F. W. Kadonsky, representing jointly the United States Department of Agriculture and the experiment stations of Wisconsin and Minnesota in cooperative experiments relating to this subject, and some of the data relating to the char-pitting method of burning stumps are taken from a report made by Mr. H. W. Sparks, of the Washington Agricultural Experiment Station, who assisted in this phase of the work. Mr. Kadonsky's report will be published in full by the Wisconsin and Minnesota stations and Mr. Sparks's report by the Washington station.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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COST AND METHODS OF CLEARING LAND IN WESTERN WASHINGTON.

INTRODUCTION.[1]

Much of the agricultural land in the United States was at one time occupied by forests. Although a large area of this land has been cleared of brush and stumps, little has been published concerning the methods and cost of preparing stump land for the plow.

In several sections of the country this question is yet an important one, but it is of the utmost importance in western Washington, where the land is for the most part covered with evergreen timber. Lumbering has been for years the leading industry of this section, resulting in large areas being stripped of merchantable timber and leaving what is locally called logged-off land, known in other States as cut-over land. The difference between the logged-off lands of western Washington and the cut-over lands of other States is chiefly in the size of the stumps. Cut-over lands are generally quite easily cleared, while to bring logged-off land under cultivation with primitive methods has been very laborious and expensive.

This land as left by the logger is thickly studded with stumps, snags, and trees unfit for lumber, among which logs, tree tops, and underbrush are strewn (fig. 1).

[1] The investigations on which this bulletin is based were begun by the Department of Agriculture in 1908. The year following the Washington State Legislature appropriated the sum of $5,000 to be used in conjunction with a similar sum allotted to the work by this Department. A portion of the funds appropriated by the State was allotted to the department of industrial chemistry of the University of Washington for use in a study of methods of utilizing for industrial purposes the materials that are ordinarily wasted in clearing land. The results of this investigation will be published separately. The remainder of the fund appropriated by the State was allotted to the Washington State Experiment Station to be used in cooperation with this Bureau in furthering the objects of these investigations. During the last two years cooperative investigations of a similar nature have been conducted jointly by this Department and the State experiment stations of Wisconsin and Minnesota.

The investigation relating to the use of waste materials was conducted by Prof. H. K. Benson, of the University of Washington. Mr. Harry Thompson has had general charge of the investigations in the State of Washington relating to cost and methods of clearing land, in which he has been assisted by Mr. H. W. Sparks, of the Washington State Experiment Station, since the appropriation of money by the State was made for this work. The details conducted in cooperation in the State experiment stations of Wisconsin and Minnesota were carried out by Mr. J. F. Kadonsky. The Washington State station will publish a special report by Mr. Sparks on the use of the char-pitting method of burning stumps, and the Wisconsin and Minnesota stations will publish a special report by Mr. Kadonsky on the use of explosives in removing stumps. Mr. Thompson has drawn freely on these two reports in the preparation of this bulletin.

It is admitted by all that of such problems the clearing of the fir lands of western Washington and western Oregon is the most difficult and the most expensive. The character of many of the stumps to be removed is shown in figure 2.

A large part of this logged-off land has been lying idle for from 10 to 20 years. During this time it has grown up in ferns, underbrush, and young evergreens (fig. 3). In this condition it has yielded nothing to the owner and very little in taxes to the State, and has become a drawback and menace to the community. During the summer months the logs, tree tops, and accumulated débris often become so

FIG. 1.—A typical clearing in western Washington.

dry that a chance spark from an engine or camp fire will start an uncontrollable blaze that often destroys standing timber and the buildings of the settlers upon these lands.

EXTENT OF LOGGED-OFF LAND.

The logged-off lands have never been segregated from the unimproved lands upon the tax rolls of most of the counties, but after deducting the acreage in tide flats, prairies, burned-over lands, and rocky wastes, there are at the present time approximately 2,500,000 acres of logged-off land in western Washington. During the years 1908 and 1909 more than 500,000 acres were logged off. In some

of the counties, where the timber has been easily accessible, more than half of the merchantable timber has been taken to the mills. It is only a question of a few years until the lumber industry in these counties will have ceased to be the support of their cities and towns. This condition has caused the people to look to the utilization of these logged-off lands for the future development and upbuilding of their communities.

UTILIZATION OF LOGGED-OFF LAND.

Notwithstanding their great extent, these logged-off lands are being brought under cultivation very slowly when compared with the area stripped of its merchantable timber. In some counties less

FIG. 2.—Typical stumps to be removed.

than 3 per cent of the area cut over each year is cleared for cultivation. The average area logged off each year exceeds that put under cultivation by approximately 250,000 acres.

It is of the utmost importance to the country that these lands be utilized, for the rapid increase in population of western Washington and western Oregon during the last decade has made a great demand for farm products. To meet this demand it has been necessary to ship into this section, with its millions of acres of idle land, enormous quantities of food supplies. As a result there has been a great demand for farm land and the question of clearing logged-off land has become a pressing one. In spite of the high cost of clearing, the increased demand for farm products is causing the fertile valleys and much of the bench lands adjacent to the cities and transportation

points to be cleared and used for gardening, truck farming, dairying, poultry raising, fruit growing, and general farming.

The present logged-off land can be used for reforesting, pasture land, or farm land. The steep hillsides, rocky knolls, and inaccessible land should be burned over directly after the logging operations have been completed, and should be allowed to reforest naturally, as most of them will do. The burning after logging is necessary, for, if allowed to grow up among the tree tops, logs, and brush, the young seedlings are nearly certain to be destroyed by fire before they reach the stage of merchantable timber.

CLEARING LAND FOR FARM PURPOSES.

The purpose of the work of investigation by this Department has been to determine the methods and cost of clearing land for farming purposes and to decide, if possible, upon a system of clearing land for general use; but these lands are often used for pasture several years before any attempt is made to prepare them for cultivation; hence, a brief discussion is given of the methods in use for converting stump land into pasture.

SLASHING.

All logged-off land should be slashed. If this is done directly after the logging the cost is found to be much less than when it is done a number of years later. The second growth comes on very rapidly and the growth in six years will more than double the cost of slashing (see fig. 3).

In slashing, the large second growth, old snags, and trees should be cut at a height of 3 or 3½ feet above the ground. This is a convenient height at which to cut them and the stumps are much easier to hitch to and to pull when the time comes to take them out. A better purchase is also had when using the stump puller. Windfalls and logs that are lying across other logs should be cut and brought to the ground as close together as possible without too much labor. The slashing should be done in the early summer; where the second growth and brush are alder, maple, and other deciduous timber, they should be cut in full leaf. When cut at this time the stumps and roots do not sprout so readily as when they are cut in the dormant season. The slashing can be burned at any time after the leaves upon the fallen trees become dry. The best time to burn is without doubt during the last of August or the first of September, when everything is the driest. The danger from fire is greatest at this time and every precaution should be taken to guard against it.

The laws of Washington require that a permit be taken out to burn slashings during the months of June, July, August, and Sep-

tember. This permit is obtained from the deputy fire warden of the county where the burning is to be done. In some localities there would be very little danger of the fire spreading; in others great risk would be run in burning at any time during the dry season. The surroundings should determine the time to burn in each locality. However, in most cases a slashing can be burned at the most advantageous time by taking the proper precautions. In burning during the dry season, a strip 10 to 20 feet wide, along the margins next the timber or any other land that has not been slashed and burned over, should be cleared absolutely clean of all material that will carry fire. Where slashings border pasture or cultivated fields there will be less danger.

FIG. 3.—Second growth, which springs up in a few years after the timber is cut.

The fire should be started very early in the morning or late at night, when the velocity of the wind is usually the least. The fire should be guarded continuously to prevent spreading to adjacent land. It is wise to place a few barrels of water at the most dangerous points, for use in an emergency. It is sometimes the safest to back-fire, starting the fire on the side toward which the wind is blowing and forcing it to burn against the wind. Where the field is large and little wind is blowing, fires can be started on both sides of the slashing.

If the large and partly decayed logs are bored and split with a small charge of powder some time before the burn, they will be more

nearly consumed. Holes should be bored in those logs that are sound enough to admit of it; those that are too much decayed for boring should be chopped as deeply as possible with a narrow-bitted ax. The powder will do better work if the holes are bored or chopped at an angle of about 45° with the center line of the log. Charge the holes in the usual way, covering the chopped holes with a shovelful or more of wet earth or clay. Good results are often obtained with not more than half a stick of powder. This shatters the log so that the air and sun have a chance to dry it out before the burn.

Cutting down the dead trees and snags prevents fire from being carried by the wind after all the fires are supposed to be extinguished. Rotten snags have been known to hold fire for several weeks.

If the tract is to be utilized for pasture, the seed should be sown in the ashes immediately after the fires of the slashing have burned out and before the first rainfall, so that the seed may be covered by the rain.[1]

Where land has been thickly covered with second growth it is economy to seed after the slashing has been burned and then pasture goats and cattle upon it for three or four years before removing the stumps. Figure 4 shows a field in the foreground where goats have been pastured, while the brush across the fence shows the growth where goats have not been pastured. By the time the pasture has worn out, the fibrous roots of the large stumps have decayed and the small stumps have rotted to such a degree that the stumping may be done much more easily and at a less cost than when they were green. The goats will keep down all second growth and brush by browsing upon them, and cows or other stock may be pastured upon the grass at the same time.[2]

Men who have run small flocks of goats upon brush land claim that the goats not only thrive on the browsing but that the work they do in one year will pay the first cost of the flock, the increase and the mohair being net. The cost of removing a stump four or five years after logging is nearly 25 per cent less than for removing a green stump. (Table I, p. 22.) The larger stumps decay very slowly and the cost of removing them at any time after they are four or five years old is practically the same. Stumps of fir and cedar which had been left for 20 years were decayed only slightly around the outside and at the top, while the roots were still solid.

If the stumps are to be taken out and the land prepared for cultivation, the slashing and burning are performed in the same manner as in preparing the land for seeding to pasture.

[1] See "The Utilization of Logged-Off Land for Pasture in Western Oregon and Western Washington," Farmer's Bulletin 462, U. S. Dept. of Agriculture, for the kind and quantity of seed to sow upon the different soils.

[2] See "The Angora Goat," Farmer's Bulletin 137, U. S. Dept. of Agriculture, and a bulletin entitled "The Goat Industry in Western Washington," Washington State Experiment Station, Pullman, Wash.

STUMPING.

It is impossible to farm satisfactorily upon land from which the stumps have not been removed, as the fir and other trees often have a very shallow system of rooting, which makes the use of modern implements for tilling the soil impossible.

Stumps are removed by heavy blasting, by the stump puller without blasting, by blasting and pulling, and by burning. The pulling is done by team and blocks, stump puller, or engine.

BLASTING STUMPS.

Explosives are used extensively in clearing new land wherever it is desired to make farm land out of what was once timbered land.

FIG. 4.—A field which has been pastured by goats, the brush on the other side of the fence showing the growth before being pastured.

These explosives are used either to blow the stumps entirely from the ground or only to split them and jar the soil from the roots, after which mechanical power is used in pulling them from the ground.

An explosion of powder is the sudden transformation of a solid into a gas, which occupies a much greater space. A common error is made by many practical men in thinking that the action of dynamite is downward instead of being in all directions. It appears to act downward from the shattering effect upon the soil, but the action in other directions is just as great, only there is usually nothing visible to show it. The action on the soil chemically is not detrimental, as is commonly believed. The burying of the topsoil under

the unproductive subsoil, thrown out in blasting heavy stumps, is detrimental and in some cases requires several years of cultivation to overcome.

METHODS OF USING POWDER IN BLASTING STUMPS.

The most economical time to blast stumps is in the rainy season, when the soil is full of water. A saturated condition of the soil is best. At this time the water fills all the air spaces, the gases are better confined, and the stumps leave the earth more easily. The saving of powder is more apparent upon loose, sandy soils when they are wet than upon clay soils. When loose soils are filled with water a small charge of powder will lift a stump that would take twice that amount when the earth is dry.

The kind of powder mostly used is known as stumping powder and is generally 20 per cent nitroglycerin, or a compound of equal strength. At this time there are only two stumping powders upon the market in this section that do not contain nitroglycerin. However, all stumping powders are quoted at the same price upon the Seattle market. In some localities it is claimed that better results are obtained by using 30 or 40 per cent nitroglycerin powder, but no one should undertake to use these higher grade powders without considerable experience in blasting. For general purposes the 20 per cent powder is found to meet all requirements of stump blasting. In land-clearing operations near Vancouver, British Columbia, 25 per cent nitroglycerin powder is commonly used.

Both nitroglycerin and the chlorate powders are used in Wisconsin and Minnesota. The nitroglycerin powder ranges from 20 to 60 per cent in strength, that most generally used being 40 per cent. The 60 per cent explosive acts very rapidly, with a cutting effect, while the 20 and 25 per cent act comparatively slowly, with a propelling force. The chlorate powder is of only one strength, equal to 40 per cent nitroglycerin, as determined in the field, but is much slower in action.

The effect of the odor of the nitroglycerin powders, or of contact with them, causes many operators to become sick. If some care is taken to keep out of the gases and to avoid handling the powder with the bare hands this sickness can, to a great extent, be avoided. Canvas gloves may be used in handling the powder; they should be discarded when they become saturated.

Chlorate powders are comparatively more stable than nitroglycerin powders. A ball from a rifle will almost always explode the latter, while the chlorate powders remain intact. The chlorate powders are put up in bulk or cartridge form and are nonfreezing; consequently they can be used in the coldest climate without thawing. They have

no odor which affects the operator, as do the nitro powders, but the chlorate powder can not be used in water unless confined in waterproof cartridges.

When powder is brought upon the farm it should be stored in a dry, well-ventilated building, at some distance from other buildings. This building should be kept locked to prevent others than the powder men from handling the explosives. Caps and fuses may be kept in the same building, but they should be kept packed in a box of sawdust until they are taken out for use in the field. This box should be kept at some distance from the boxes of powder.

The fuse should be of good quality, free from imperfections, and waterproof. An imperfect fuse will cause misfires or delayed blasts. It is safe to say that most of the painful and fatal accidents that have occurred in stump blasting have resulted from delayed blasts caused by a defect in the safety fuse. A shot should never be investigated immediately that does not explode when it should. It should be left for several hours and no work should be done around or very near the stump under which the charge has failed to explode. After the danger is past, the charge may be exploded by carefully placing and firing a small charge near the one that did not explode.

The blasting cap or the electric fuse is used to detonate the charge. The power developed and the success of the blast depend upon the perfect detonation of the charge. It is inadvisable to use less than a 5X cap; when the powder is chilled a 20-grain cap will give better results. Powders other than nitroglycerin require a stronger cap; when using them no cap of less strength than the 20-grain cap should be used. Caps should always be protected from moisture and dust. Unless thus protected the caps frequently fail to explode, causing misfires, which are the source of most of the accidents in blasting stumps.

THE PRIMER.

The cartridge in which the cap is fixed is called the primer. It is necessary to have one in each charge, regardless of the size of the charge. The primer is made as follows: The end of the fuse is cut squarely across. The cap is then placed gently on the end of the fuse. The fuse should never be twisted into the cap or inserted so far that it touches the bottom, as the fulminate within the cap is very sensitive. If the fuse is slightly too large, its size may be reduced by scraping it with a knife. The cap should be handled with great care. The cap is fastened on the fuse by means of the cap crimper, which resembles a pair of pliers. The crimp is made at the point where the fuse enters the cap. No pressure should be given the cap at any other point. When working in wet soil a small amount of soap or tallow should be rubbed around the point where the fuse and cap

meet, in order to keep out the moisture. A stick of powder, which is usually $1\frac{1}{4}$ inches in diameter by 8 inches long, is opened at one end and a small hole made in the powder by means of a stick the size of a lead pencil, or the round handle of the cap crimper. The cap that has been fastened to the end of the fuse is now inserted into this hole to the depth of the cap, and cartridge and fuse are tied securely together by means of a short length of twine. The fuse should not enter the powder, as the side spitting might ignite the explosive, causing it to burn instead of exploding.

The primer is often made by inserting the cap crimped to the fuse into a hole made diagonally in the side of the cartridge, the fuse being tied to the cartridge as before. The method first described is thought to be the better of the two.

In making the primer for firing by electricity it is recommended that the cap to which the wires are attached be inserted in a hole made in the end of the cartridge and the wires tied to the cartridge as in the case of the fuse.

THAWING THE POWDER.

When using nitroglycerin powder in cold or even moderately cold weather it is necessary to thaw it, as all strictly nitroglycerin powders freeze at a temperature of 50° F. Frozen powder should never be used, as it is dangerous to handle and does not give satisfactory results. Some means of thawing powder must be provided when using it in cold weather. Powder is frozen when the stick feels hard to the touch. It is in good condition when soft.

When using powder upon a large scale a small building heated by hot-air or hot-water pipes is the best method of keeping it in good condition. Powder can be thawed by burying it in fresh horse manure in water-tight boxes. It should never be steamed or subjected to a high temperature and should be heated gradually when it becomes necessary to thaw it. It is very often thawed by standing it in boxes before an open fire, but this should never be done, as it is dangerous. The double hot-water kettle used by some is rather unsatisfactory unless only a small quantity of power is needed. In cold weather it is more economical to use a powder that does not require to be thawed when working.

DIGGING HOLES UNDER THE STUMPS.

Putting the holes under the stumps is without doubt the most important as well as the most laborious part of stump blasting. The tools needed in making the holes are a bar 6 or 7 feet long, a long-handled shovel, a 3-inch auger with a long shank and crossbar handle (fig. 5), a narrow shovel or a spoon with a long handle, and an ax.

The bar is best made by welding steel points upon the ends of a 1½-inch iron pipe. One end should be round, for dislodging gravel and small stone; the other should be a sharp chisel point for cutting small roots. A good spoon may be made by turning up the sides of a long-handled shovel. When loading the holes a tamping stick 2½ inches in diameter at one end is needed. There should be no metal about this stick. A supply box can be made from an empty powder box by placing partitions where wanted and nailing a wooden hoop to the box for a handle. It is useful in carrying caps, fuse, twine, crimpers, and a small supply of explosives.

The common way of placing the charge is to bore the hole under the stump, terminating it at the center and pressing the cartridges

FIG. 5.—Beginning the boring of holes under a stump for blasting.

down unbroken. This leaves the charge out of the center of resistance and the result is not satisfactory. The bored hole should go under the stump at an angle of about 45°, although this can be varied to suit the circumstances. (See fig. 5.) The bottom of the hole should be slightly beyond the center of resistance and from 18 inches to 3 feet below the ground line of the stump. This permits the proper placing of the charge.

The hole should be made, if possible, between two prominent roots which come close together. There are two reasons for this: (1) There is less chance for the force to blow out of the hole, because of the

resistance offered by these roots, and (2) there are generally no small roots immediately behind these larger ones and, consequently, there is less chance of meeting with an obstruction in making the hole. The holes under stumps less than 30 inches in diameter can be made with a 3-inch auger, and much time is saved by its use unless the soil contains too much gravel. The holes under the larger stumps should be dug with bar, shovel, and spoon.

A great deal of time can be saved in digging holes in gravelly soil, or where many small roots are in the way, by using a part of a stick of powder to loosen the gravel and to break off the roots. A cap and a short piece of fuse is attached to the powder as in making the primer for a charge. This short piece of powder is placed against the obstruction, lightly tamped, and discharged. The force of this small explosion generally renders conditions such that the process of digging the hole can easily be continued. This charge, costing a few cents, often saves an hour's work and enables the charge to be placed where the maximum amount of work will be done. Where the hole can not be enlarged enough at the bottom to hold the charge a half stick of powder will often loosen the roots, gravel, or other obstruction so that the load can be properly placed after cleaning out the loosened material. The hole should not be made any larger than necessary to hold the charge, as the earth can never be packed as solidly as it was in the first place. Often an obstacle is encountered in making a hole under a stump before the proper depth is reached. When this is the case the operator frequently increases the charge of powder, thinking it will do the work as well as the smaller charge when properly placed. This, however, is not the case. The side of the stump is blown away, leaving many of the roots and often half of the stump behind. The charge should always be placed under the center of resistance of the stump. Time is well spent in doing this.

When a stump is located on a slope the center of resistance and the center of the stump are not the same; hence, when the charge is placed under the center of the stump only part of it is blown out. Here the resistance is greater toward the higher slope and consequently the charge must be placed beyond the center of the stump to get it in the center of resistance. Often the root formation is greater on one side of a stump than on the other, and when the charge is placed under the center of the stump the force takes the path of least resistance, shooting out at one side. To remedy this, place the charge toward the heavy root formation, which will bring it under the center of resistance and give better results. Sometimes large logs are found lying so near a stump that more resistance is offered upon that side than upon the other; this must also be taken into consideration when blasting.

PLACING THE CHARGE.

When the hole under the stump is completed, if there is no water in the hole it is good practice to remove the paraffin wrappers from the powder and to pour the powder loosely into the hole, packing it firmly but with care. The quickest and most satisfactory way is to slit the wrappers lengthwise with a sharp knife. When the split cartridge is pressed against the bottom of the hole with the tamping stick the cartridge bulges and crumbles into a mass that packs easily. When placed in a cylindrical hole the cut parts bulge so as to fill the opening completely, thus making the charge compact, which is desirable. Care should be taken while packing the charge not to strike a heavy blow, but the powder must be packed sufficiently to avoid the presence of air pockets.

The primer is the last of the charge and is placed upon the charge, care being taken not to tamp it. The end of the fuse should be held against the side of the stump and fine earth sifted upon the charge to the depth of an inch or so and packed lightly with the tamping stick. After 4 or 5 inches of fine earth have been packed lightly but firmly, the filling can be shoveled in and should be packed solidly by hand as the hole is filled to the surface of the ground. Upon the tamping depends much of the success of the shot. A wooden tamping stick should always be used.

If there is water in the hole under the stump the powder should not be taken out of the wrappers, but the sticks should be tied into bundles with the primer in the center and the bunch shoved to the bottom of the hole by means of the tamping stick. Where the material will permit it the tamping should be done in the same manner where there is water in the hole as where the hole is dry.

The most common way of lighting the fuse is to split the end for an inch or more and light it with a match. The quickest and most satisfactory way when matches are used is to thrust the head of the match that is just starting to burn into the split end of the fuse. This seldom fails to light the fuse no matter how hard the wind blows. It is well to scratch the match on an object quite close to the end of the fuse, so the match can not burn long before being thrust into the fuse, which is important in this method.

When a number of stumps are to be fired at once, a live firebrand, a 1-inch rod 3 feet long heated in a burning rubbish pile, or a lighter made from a short piece of fuse is recommended. A good lighter is made by nicking a short piece of fuse every 2 inches, making as many nicks as there are fuses to light. By lighting this at the end and holding it so that the fire will shoot downward from the nicks, it can be used to fire the shots, as the fire spitting from the nicks upon the

split ends of the fuse lights them very readily. The rate at which the lighter burns also gives the powder man an idea of how fast the fuse upon the first primer lighted is burning.

The condition of the soil with respect to moisture is an important factor in determining the amount of explosive required per stump. Owing to the great variation in soil conditions it is not possible to give the exact quantity of powder required for stumps of different sizes, but Table I, compiled from records kept during actual clearing operations on the kinds of soils indicated, will give an approximate idea. Extremely loud reports and the throwing of the parts of the stump to great distances indicate an excessive use of the explosive. The splitting and lifting of the stump just out of the ground, accompanied by a deadened report following the explosion, shows economical use of the powder.

COST OF BLASTING STUMPS.

Table I gives the quantity of explosive used under various sizes of stumps of different kinds. Each stick composing the charge is $1\frac{1}{2}$ inches in diameter by 8 inches long. A 50-pound box of powder contains an average of 65 sticks; hence, a single stick weighs practically three-fourths of a pound. The right-hand column shows the average cost of blasting the different sizes of stumps and includes the cost of the powder, fuse, and caps, as well as the cost of labor in digging the hole and in loading and firing the blast. The effect is good except as stated.

The green fir stumps in sandy, gravelly loam were to be piled without the use of mechanical power and therefore required more explosive than others which were to be pulled by donkey engine. The holes were made with an auger and enlarged at bottom with a spoon bar. The stated depth of hole refers to its slanting measurement and not to its vertical distance below the ground line. One stick of 40 per cent nitroglycerin powder was used as a primer. The fuse used was 5 feet long.

TABLE I.—*Data showing the cost of blasting stumps of different sizes under varying conditions.*

GREEN FIR STUMPS IN SANDY, GRAVELLY LOAM.[1]

Dimensions of stumps (inches).			Number and kind of nitroglycerin sticks in charge.		Depth of hole (inches).	Average cost per stump, including labor.
Height above ground.	Diameter at—		20 per cent strength.	40 per cent strength.		
	Ground.	Cut-off.				
28	18	12	3	.....	24	
30	16	12	3	.....	20	
30	16	12	3	.....	20	$0.35
27	16	12	3	.....	24	
28	16	12	3	.....	24	
38	18	13	4	.....	28	.....
30	24	[2] 16	3	.....	20	.....
40	22	16	5	.....	24	.....
30	20	18	5½	.....	30	
30	22	18	5	.....	30	.51
30	24	18	6	.....	36	
36	30	21	14	.....	40	.....
36	30	22	14	.....	40	.....
33	30	24	13	.....	30	1.26
30	36	25	15	.....	42	.....
30	38	26	18	.....	36	.....
33	38	27	18	.....	40	.....
30	42	30	24	.....	44	
36	36	30	24	.....	46	1.74
36	34	30	14	.....	32	
30	42	31	25	.....	42	.....
36	40	34	18	.....	36	.....
32	40	34	25	.....	36	.....
36	48	36	20	.....	41	
30	48	36	26	.....	36	1.98
42	44	36	30	.....	36	
36	50	42	30	5	36	.....
30	56	45	24	4	42	.....
27	60	45	40	5	42	.....
30	58	48	36	3	50	2.88
Average..	.....	[3] 30.4	.....	.....	.....	1.40

FIR STUMPS IN GRAVELLY LOAM, FIVE YEARS AFTER LOGGING.[4]

108	30	18	3	.....	24	
48	24	18	4	.....	18	
42	24	18	6	.....	36	$0.47
36	30	18	6	.....	24	
30	24	18	2	.....	18	
54	36	22	3	.....	18	.....
48	40	24	5	.....	24	
18	30	24	3	.....	42	.57
30	34	24	3	.....	30	
60	40	26	7	.....	36	.....
78	42	30	15	.....	36	
66	45	30	20	.....	36	
48	45	30	6	.....	24	1.15
84	50	30	10	.....	24	
66	48	30	8	.....	30	
84	48	36	20	.....	36	
66	60	36	17	.....	36	
84	60	36	17	.....	24	1.49
72	48	36	14	.....	42	
60	50	36	10	.....	36	
60	70	48	25	.....	42	
66	72	48	21	.....	48	
90	76	48	23	.....	48	2.21
84	72	48	25	.....	39	
96	72	48	25	.....	42	

[1] Conditions very unfavorable; atmospheric temperature about 40° F.; land logged off in 1909, blasting done in winter of 1910–11.
[2] Fair effect.
[3] For 29 stumps.
[4] Logged off in 1905; stumps to be pulled by donkey engine.

TABLE I.—*Data showing the cost of blasting stumps of different sizes under varying conditions*—Continued.

CEDAR STUMPS IN GRAVELLY SOIL, FIVE YEARS AFTER LOGGING.[1]

Dimensions of stumps (inches).			Number and kind of nitroglycerin sticks in charge.		Depth of hole (inches).	Average cost per stump, including labor.
Height above ground.	Diameter at—		20 per cent strength.	40 per cent strength.		
	Ground.	Cut-off.				
27	36	22	2	.....	24	.....
36	32	24	3	.....	24	
48	42	24	2	.....	24	$0.41
48	36	24	2	.....	18	
30	38	24	2	.....	24	
84	42	30	5	.....	24	
72	54	30	6	.....	30	.64
48	48	30	3	.....	18	
42	45	30	4	.....	36	
72	48	32	7	.....	42	.....
36	40	36	6	.....	24	
36	48	36	5	.....	36	.74
48	60	36	7	.....	30	
78	60	39	5	.....	42	.....
75	54	40	5	.....	18	.....
66	90	44	10	.....	42	.....
72	70	45	15	.....	48	.....
60	72	48	10	.....	24	1.35
90	66	48	12	.....	30	
42	72	50	15	.....	48	.....
102	118	58	20	.....	42	.....
90	108	60	14	.....	[2] 30	
48	98	60	15	.....	42	1.67
78	87	60	12	.....	36	
66	115	62	15	.....	36	.....
120	108	70	19	.....	36	.....
108	120	72	24	.....	36	1.93
120	118	78	8	.....	36	.....

COTTONWOOD STUMPS IN LOOSE SANDY LOAM.[3]

48	36	24	6	.....	.....	
48	36	24	6	.....	.....	
48	42	24	6	.....	.....	$0.64
36	36	24	5	.....	.....	
48	36	24	6	.....	.....	
36	48	36	8	.....	.....	
36	48	36	7	.....	.....	
24	42	36	6	.....	.....	.93
48	48	36	7	.....	.....	
48	48	36	13	.....	.....	
96	72	48	26	.....	.....	
84	60	48	20	.....	.....	
36	60	48	18	.....	.....	1.98
48	60	48	18	.....	.....	
84	72	48	22	.....	.....	
84	96	60	27	.....	.....	
96	72	60	26	.....	.....	
96	84	60	28	.....	.....	2.61
96	84	60	29	.....	.....	
96	84	60	29	.....	.....	
120	84	[4] 72	41	.....	.....	
96	108	[4] 72	25	.....	.....	
84	96	[5] 72	43	.....	.....	3.36
96	96	[5] 72	40	.....	.....	
96	96	[5] 72	32	.....	.....	

[1] Stumps on high ground; to be pulled and piled by donkey engine.
[2] Three holes required.
[3] The texture of the soil made blasting difficult. Logged off in 1904 except as noted. The smaller stumps were much older than the larger ones, making them cheaper to blast.
[4] Logged off in 1906.
[5] Logged off in 1907.

TABLE I.—*Data showing the cost of blasting stumps of different sizes under varying conditions*—Continued.

OLD SPRUCE STUMPS IN SANDY SILT SOIL.[1]

Dimensions of stumps (inches).			Number and kind of nitroglycerin sticks in charge.		Depth of hole (inches).	Average cost per stump, including labor.
Height above ground.	Diameter at—		20 per cent strength.	40 per cent strength.		
	Ground.	Cut-off.				
24	48	36	14	.....	.....	
72	48	36	13	.....	.....	
96	60	36	15	.....	.....	$1.40
48	48	36	10	.....	.....	
72	48	36	10	.....	.....	
60	60	48	25	.....	.....	
72	60	48	22	.....	.....	
96	72	48	24	.....	.....	2.53
96	96	48	38	.....	.....	
72	60	48	35	.....	.....	
96	84	60	30	.....	60	
72	84	60	35	.....	84	
60	84	60	35	.....	72	3.06
180	180	60	40	.....	84	
120	120	60	30	.....	72	
96	18	72	35	.....	96	
108	20	72	30	.....	84	3.45
120	10	72	40	.....	84	
96	10	72	55	.....	78	
108	10	84	55	.....	84	4.45
96	15	84	40	.....	96	
180	20	96	60	.....	78	5.50

ALDER STUMPS IN SILT SOIL.[2]

48	18	12	1	.....	24	
36	18	12	1	.....	30	
36	24	12	1½	.....	24	$0.18
72	24	12	1½	.....	24	
60	30	12	1½	.....	24	
24	24	18	2	.....	.....	
24	24	18	2	.....	.....	
48	36	18	2	.....	.....	.26
36	24	18	2½	.....	30	
48	24	18	2½	.....	.....	
24	30	24	2	.....	.....	
36	30	24	3	.....	.....	
36	30	24	2	.....	.....	.30
48	36	24	2	.....	.....	
36	36	24	3	.....	36	
48	48	30	3	.....	.....	
24	36	30	4	.....	.....	
30	36	30	5	.....	.....	.51
48	36	30	8	.....	.....	
48	42	30	4	.....	.....	
36	48	36	6	.....	48	
36	42	36	8	.....	60	.76
24	42	36	7	.....	48	
72	48	36	10	.....	48	

[1] Skagit River Valley land logged off in 1896; stumps to be pulled by donkey engine.

[2] Valley land, logged off in 1904; stumps to be pulled by donkey engine. Alder stumps should not ordinarily be blasted or pulled when green, as they decay rapidly and are easily removed after 3 or 4 years. Many of the 12-inch and 18-inch stumps were pulled without blasting.

TABLE I.—*Data showing the cost of blasting stumps of different sizes under varying conditions*—Continued.

FIR STUMPS IN VALLEY SOIL WITH CLAY SUBSOIL.[1]

Dimensions of stumps (inches).			Number and kind of nitroglycerin sticks in charge.		Depth of hole (inches).	Average cost per stump, including labor.
Height above ground.	Diameter at—		20 per cent strength.	40 per cent strength.		
	Ground.	Cut-off.				
42	36	24	3	.....	48	
36	48	24	8	.....	48	
60	60	24	6	.....	48	$0.62
36	36	24	4	.....	24	
84	42	24	6	.....	24	
96	72	36	6	.....	36	
78	48	36	10	.....	60	
60	48	36	12	.....	60	1.10
96	72	36	12	.....	60	
48	48	36	12	.....	48	
96	144	48	15	.....	84	
84	72	48	15	.....	72	
90	84	48	12	.....	48	1.46
90	84	48	12	.....	72	
72	72	48	10	.....	72	
192	120	60	25	.....	72	
96	96	60	23	.....	72	
156	120	60	15	.....	84	1.98
108	96	60	15	.....	84	
84	84	60	14	.....	72	

[1] Land logged off in 1899. Conditions favorable for blasting; stumps to be pulled by donkey engine.

THE ELECTRIC BATTERY IN STUMP BLASTING.

Although the electric battery has been used to fire blasts in mines and in other work for many years it has not been used extensively for firing blasts under stumps until quite recently. In many cases its use will result in the saving of powder, while in others no saving will be effected. In all cases the liability of accidents is less than where the shots are fired by the safety fuse. There is never a delayed blast, and a misfire is very rare. When a misfire does occur it is not necessary to suspend work in the vicinity for some time before one can investigate the failure.

By using a battery the holes can nearly always be made by an auger (figs. 5 and 6), as two or more small charges may be used instead of a single large one. This especially applies to hollow stumps, stumps that are burned in the center or down to the ground, or two stumps with the roots grown together. (See fig. 7.) Many stumps can be economically removed by two charges, fired simultaneously, where it would be impossible to place a single charge of the same amount of powder to do the same work. With the battery there is no time lost in waiting for the fuse to burn, the débris is not thrown so far, and less time is required to fill the excavations because they are not so deep.

The disadvantages of using a battery are: (1) More labor is required in handling the leading wire, making the connections, and digging and loading the extra holes required, (2) more detonators are used, and (3) more time is required to blast a given number of stumps.

Where the stumps root deeply and are solid the use of a battery effects no saving, but where there are a large number of hollow cedar stumps or shallow-rooted fir stumps a battery may be used to good advantage.

METHODS OF USING THE BATTERY.

The priming, loading, and tamping are done in the same manner as when the safety fuse is used. The electric fuse is used instead of

FIG. 6.—Finishing the boring of holes under a stump for blasting.

the blasting cap and safety fuse. The 6-foot fuse is the best for general use. This length will nearly always reach from one charge to the next. When all the charges are in and tamped, the wires of the fuses are separated and connected to the other fuse wires and to the battery so that they make a continuous circuit. That is, one wire is connected from the first fuse to a wire from the second fuse. The other wire of this second fuse is connected to one of the wires from the third fuse, and so on to the last fuse. One wire from each of the first and last fuses is left to be attached to the battery.

If the fuse wires are not long enough a short piece of insulated copper wire is used to join them. After a few shots, much of the

fuse wire can be picked up and used for connecting wire. All wire ends should be scraped clean and bright before they are connected. When working in the rain the joints should be covered with tape. Usually it is sufficient to keep the joint off the ground and off wet stumps or logs. After the charges are all connected, except at one point, the two free wires are joined to the leading wires of the battery and insulated if they can not be kept off the ground.

The leading wires should be long enough to reach at least 300 feet from the blast. When possible the blasting machine should be placed behind a tall stump or a tree before firing the blast.

The blasting machine can be procured from any electric supply house or from the powder companies. It should be large enough

FIG. 7.—Two stumps whose roots are so grown together that a single charge can not be placed to blast them economically.

to fire from 1 to 30 charges at one time. It may be either a pull-up or a push-down machine. In either case it should be operated with some force. A push-down machine is preferred.

The leading wires should not be connected to the binding posts upon the top of the blasting machine until everything is ready and everyone is out of the danger zone. After each blast these wires should be disconnected. If care is used little difficulty is experienced from having the wires entangled with the stumps and roots after they are blown out, or from having them blown out. The work should be commenced at the farther side of the tract and the leading wires kept pulled away from the blasted portion of the field.

Figure 8 shows the result of a battery shot upon the stumps shown in figure 7. Fifty sticks of powder (39 pounds) were divided into 4 charges and fired by the battery. This is a saving of 15 pounds of powder and is a more effective shot than could be secured by the use of the safety fuse. Figure 9 shows the result of shooting a similar pair of stumps by the safety-fuse method. The stump on the left was not thrown out, as the charge under the right-hand stump exploded before the other, destroying the effect of the charge upon the left.

COST OF USING THE ELECTRIC BATTERY.

Comparative work with the electric battery and the ordinary fuse for blasting stumps shows twelve 36-inch green stumps shot by

FIG. 8.—The result of a battery shot upon the stumps shown in figure 7.

the battery at a cost for powder of $1.46 each and twelve 36-inch green stumps shot by fuse at a cost for powder of $1.66 each.

This shows a saving in powder of about 12 per cent upon this size of stumps. Smaller stumps will give a smaller saving and larger stumps will often give a much larger percentage of saving in the cost of powder used.

Where the auger can be used for boring the holes the cost of labor when using the battery will be about the same as where the holes are dug for the fuse shot. Where it is necessary to dig the holes by other means than the auger the saving in powder by using the battery will be offset by the extra labor and fuses required.

The tests of the various brands of stumping powder upon the market show that there is very little difference in the efficiency of the different kinds when properly used and placed under the best conditions.

In another experiment 78 old cedar stumps and roots were blasted, the firing being done by battery. The ground was low and wet, with a clay subsoil, an ideal condition for blasting. Many of the stumps had previously been burned out in the center, leaving the roots more or less detached and making it impossible to blast them by the method of a single charge under a stump.

FIG. 9.—Two stumps, similar to the ones shown in figure 7, that were shot by the fuse method. The stump upon the left was not thrown out, as the charge under the right-hand stump exploded first, destroying the effect of the charge under the stump upon the left.

A 3-inch auger was used to bore holes under the roots and stumps. The holes were bored from 18 inches to 2 feet deep. From one to three sticks of powder were used in each hole. The fuses were connected together and to the battery by 500 feet of leading wire.

Seventy-eight stumps and roots were shot, requiring 306 pounds of powder and 312 fuses. It took two men four days to do the work. The average cost per stump was as follows: Labor, $0.26; powder, $0.47; and fuses, $0.16; making a total of $0.89.

This is considered to be the most economical method of dealing with stumps of this character under these conditions.

STUMP PULLERS.

TYPES OF STUMP PULLERS AND METHODS OF USING THEM.

The stump puller has been in use for many years. While it is a slow and somewhat unsatisfactory method of clearing land, many small tracts have been cleared by its use. There are two kinds of stump pullers, those that pull the stump to the side and those that lift it vertically out of the ground (figs. 10 and 11). When using either of these machines in western Washington it is necessary to crack and loosen all except the small stumps by a charge of powder before pulling them. Most of the stump pullers are built to pull from the side and embody the principle of the capstan, having a long sweep

FIG. 10.—The simplest form of a stump puller. This pulls the stump to the side. It is operated by one man and a horse.

at the end of which one or two horses are hitched. The horses travel in a circle, thus winding the cable around a drum. These machines may be anchored in one place, so that all the stumps in a radius of 50 feet or more may be pulled from one setting, while the vertical-lift machine is set directly over the stump and must be moved every time a stump is pulled.

Another disadvantage of the vertical stump puller is the difficulty of getting a hitch on the stump to be pulled, as a chain must be passed under one of the large roots. This means that, after a stump has been cracked by a small blast, holes must be dug under each root in order to get hold of it. It will be seen from this that the time

taken to move the machine and to make the hitches consumes the greater part of the working day. After the stumps have been pulled they are more in the way than before, and the size and ungainly shape of the larger pieces make them extremely hard to handle. They are heavy and require a team and two men to put them into piles for burning. All such work is slow and much time can be wasted by those engaged in it.

The stump puller is now used very rarely upon large tracts of heavy clearing and only occasionally upon small tracts, as it has been found cheaper to blast sufficiently to permit a team to pull the remaining roots or to permit an engine to pull and pile the stumps

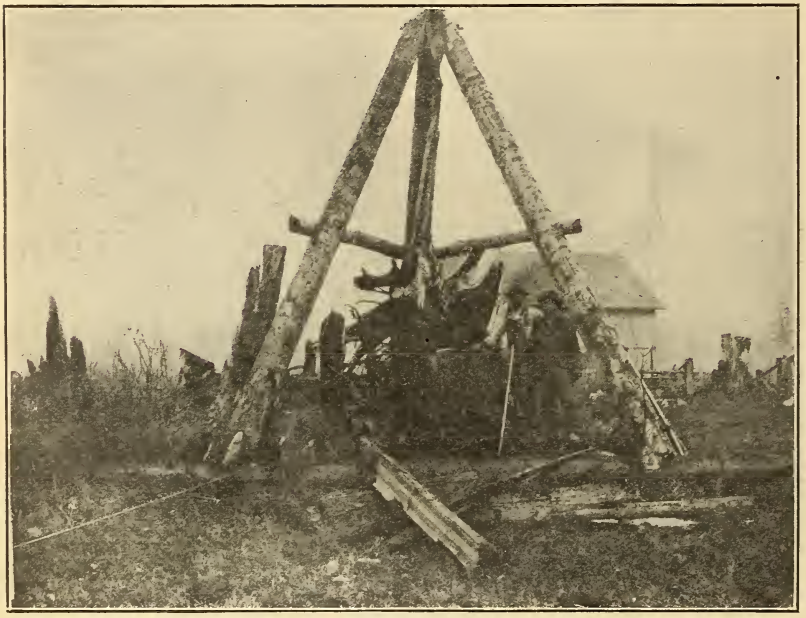

FIG. 11.—A stump puller that lifts the stump vertically out of the ground.

after blasting. Where small stumps and second growth predominate upon a tract which it is necessary to clear at once, a stump puller can be used to advantage, especially if cheap labor can be had. Thus, a farmer with several boys or an industrial school may sometimes use this method to advantage.

There are many devices in the shape of stump pullers upon the market. The more intricate of these have been tried and found wanting. In selecting a stump puller those of the simplest design should have the first choice, as they generally are the cheapest and give better satisfaction. Those that pull from the side are best for stumps that do not have a taproot.

COST OF USING THE STUMP PULLER.

Clearing No. 1: 2.2 acres low meadow land having a silt soil. All logs and small stumps had been removed at some previous time leaving nothing but the larger stumps. The outfit consisted of a stump puller (vertical lift, as shown in fig. 11), shovels, axes, bar, and mattock.

TABLE II.—*Cost of labor and material used in clearing tract No. 1.*

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
2 machine men	5	$2.50	$25.00
1 team and teamster	5	5.50	27.50
1 team and teamster	4	5.50	22.00
1 powder man	1	3.00	3.00
Rent of machine	5	4.00	20.00
Stumping powder, 32½ pounds, at 11 cents per pound			3.55
Caps and fuses			.30
Burning stumps			22.00
Repairs			4.00
Total			127.35
Average per acre			57.89
Average cost per stump, including burning			3.11

TABLE III.—*Stumps pulled, tract No. 1 (10 years after logging).*

Kind of stumps.	Diameter of stumps (inches).								Number of stumps.
	18	24	30	36	42	48	60	Average.	
Cedar	1	2	6	4	5	12	9	43.8	39
Fir				1		1			2
Total									41

Clearing No. 2: 1.5 acres of gravelly loam, bench land; no second growth; 57 logs were piled and burned with the stumps; outfit same as in clearing tract No. 1.

TABLE IV.—*Cost of labor and material used in clearing tract No. 2.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
2 machine men	4½	$2.50	$22.50
2 teams and teamsters	4½	4.00	36.00
Labor in finishing after stumps were pulled			30.00
Stumping powder, 31 pounds, at 13 cents per pound			4.00
Caps and fuse			.40
Total			93.00
Average per acre			62.00
Average cost per stump, including burning			2.02

[1] Machine owned by operator.

TABLE V.—*Stumps pulled, tract No. 2.*

Kind of stumps.	Diameter of stumps (inches).												Number of stumps.
	6	8	10	12	18	24	30	36	42	48	64	Average.	
Cedar	....	....	....	....	1	1	3	3	2	4	1		15
Fir	....	....	....	....	....	1	....	2	....	1	....		4
Hemlock	....	....	....	....	....	2	....	....	....	....	....		2
Spruce	....	....	....	....	....	....	....	1	....	....	....	$23\frac{1}{2}$	1
Alder	2	5	....	....	....	1	....	....	....	....	....		8
Maple	....	4	5	3	3	1	....	....	....	....	....		16
Total	....	....	....	....	....	....	....	....	....	....	....	....	46

Clearing No. 3: 1.5 acres in an old meadow; no undergrowth or down logs; outfit same as in clearing tracts 1 and 2.

TABLE VI.—*Cost of labor and material used in clearing tract No. 3.*

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
2 machine men	4	$2.50	$20.00
2 teams and teamsters	4	4.00	32.00
Labor in finishing after stumps were pulled	....	....	30.00
Stumping powder, $15\frac{3}{4}$ pounds, at $12\frac{1}{2}$ cents per pound	....	....	1.90
Caps and fuse	....	....	.10
Total	....	....	84.00
Average per acre	....	....	56.00
Average cost per stump, including burning	....	....	2.71

TABLE VII.—*Stumps pulled, tract No. 3.*

Kind of stumps.	Diameter of stumps (inches).											Number of stumps.
	12	18	24	30	36	42	48	60	72	96	Average.	
Cedar	3	....	4	4	2	....	....	....	....	3		16
Fir	1	....	1	3	....	....	1	6	1	....	41	13
Maple	1	....	....	....	....	1	....	....	....	....		2
Total	....	....	....	....	....	....	....	....	....	....	....	31

Clearing No. 4: 1.5 acres in an old meadow; silt soil; no brush or logs; outfit same as in clearing tracts 1, 2, and 3. No powder used.

TABLE VIII.—*Cost of labor and material used in clearing tract No. 4.*

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
2 machine men	6	$2.50	$30.00
2 teams and teamsters	6	5.50	66.00
Rent of machine	6	4.00	24.00
Cost of piling stumps and burning them	....	....	20.00
Total	....	....	140.00
Average per acre	....	....	93.35
Average cost per stump after burning	....	....	7.00

TABLE IX.—*Stumps pulled, tract No. 4 (20 years after logging).*

Kind of stumps.	Diameter of stumps (inches).							Number of stumps.
	24	48	60	72	96	120	Average.	
Cedar	....	2	1	1	5	6	82.2	15
Fir	1	....	....	....	....	....		1
Cottonwood	1	1	....	....	....	....		2
Spruce	....	1	....	1	....	....		2
Total	....	....	....	....	....	....	....	20

THE DONKEY ENGINE.

The donkey engine has been used in land clearing in western Washington for about 10 years. It has been used most extensively in Skagit and Whatcom Counties, Wash., and in British Columbia. Since it came into use more land has been cleared by means of the

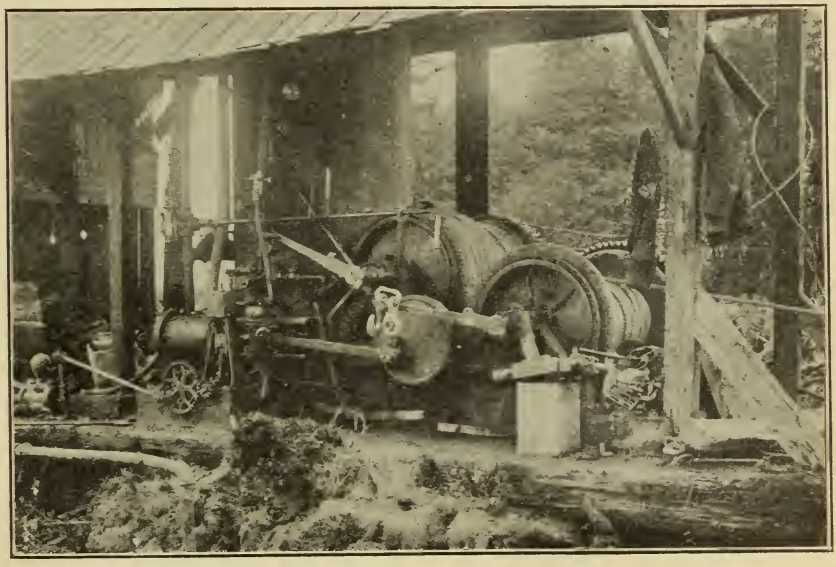

FIG. 12.—A new donkey engine used for clearing land.

donkey engine than by all other methods combined. During 1910 about 500 acres were cleared by donkey-engine outfits in British Columbia. About 25 such outfits are at work at the present time upon 1,500 acres. The cost of clearing in that country is great, owing to the fact that most of the land cleared has been logged off for more than 20 years and is covered with a dense growth of small trees 3 to 12 inches in diameter.

The engines used for this work are usually designed for and used in logging operations for some years and are not always in the best of condition. The one shown in figure 12 is a new engine bought for clearing land.

It is obvious that the use of an antiquated or worn-out engine is a handicap to the work and adds to the cost of the operation; but as the cost when new is in many cases prohibitive, many old and worn-out outfits are to be found at work. With the more successful operators it is the practice to use a large engine (10 by 12 to 12 by 14 inches in diameter of cylinder and stroke of the piston) in fairly good condition. The tackle usually consists of 1,000 feet of $1\frac{1}{8}$-inch main-line wire cable, 2,000 feet of $\frac{5}{8}$-inch haulback line, four 1-inch guy lines (may be old cable), two 10-inch pole blocks, four 8-inch blocks for the haulback line in the field, lead lines, chokers, extras, and tools. The ropes or lines mentioned are all wire cables.

Nearly all now use the gin pole in the work, as it has been proved that to use a standing tree or to pile the stumps and logs into a windrow is not an economical method of doing the work. The length of

FIG. 13.—A tall gin pole and a good pile that will burn well.

the gin pole depends upon the size of the tract to be cleared. They are usually from 60 to 100 feet in height. When a short pole is used the base of the pile covers a large area of ground, and it is not possible to build as good a pile as when a tall pole is used. Figure 13 shows a well-made pile, in making which a tall pole was used. The windrow method of piling stumps and débris is never used by the more experienced operators, as too much time is lost in keeping the lines clear and in moving the engine.[1] More land is burned over in burning the windrows than in burning the tall piles.

The logs upon the tract furnish the fuel for the engine. Where the clearing is in a valley similar to the Skagit, water may be obtained by driving a pipe to a depth of from 10 to 12 feet near the engine, when a hand pump may be attached. A steam pump is shown in figure 12 attached to a pipe driven to the water level. Upon the

[1] This statement does not apply to engines designed for use in piling stumps in windrows.

higher lands it is often necessary to haul water in tanks during the dry season of the year.

The crew generally consists of an engineer, fireman, pile man, hook tender, and assistants. Some outfits employ a man to saw wood for the engine and a signalman who works in the field when not needed for signaling. The manner of working is as follows: The tract to be cleared should be prepared by slashing, burning, and by blasting the stumps. It is not necessary that the stumps be shot entirely out of the ground. All that is required is that they be split into three of four pieces and well loosened. If the blasting is not well done the resulting delays to the work will cost more than the extra quantity of powder would have cost to do the blasting well in the first

FIG. 14.—Raising the gin pole.

place. After this has been done, the hole for the gin pole is dug in the center of a tract of about 10 acres.

If the tract does not lie in a square the work is laid out so that the maximum haul is not over 500 feet. If the work is upon low land four holes are dug, from 4 to 6 feet deep and 18 feet long, in which logs are buried. The guy lines which hold the gin pole are fastened to these logs. When upon high land, where the stumps root deeply, four stumps are left unblasted, to which the guy lines are fastened. A hole must also be dug a short distance back of where the engine is to stand, in order to anchor the engine to a buried log.

After the engine has been brought to the place where it is to stand, the gin pole is hauled to position by means of the main line and the guy lines and blocks are fastened to it (fig. 14). The haulback-line

block is fastened about 4 feet above the main-line block and the four guy lines are fastened at the top of the pole. The pole is then raised by means of the main line, and the guy lines are made taut by a pull on them with the engine and then fastened. The haulback line is then passed around one-quarter of the tract, through the blocks at the corners, and made fast to the main line (fig. 15). This is a laborious process if done by hand, as it often must be where a horse or team can not be driven around the field. It requires about eight

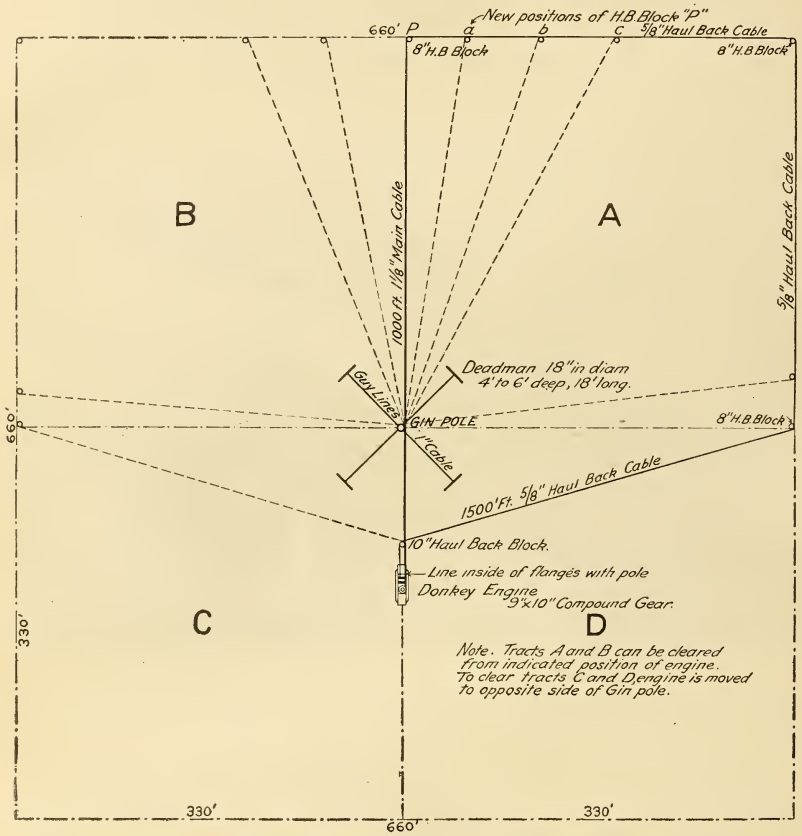

FIG. 15.—Diagram showing the position of the donkey engine and rigging for clearing a 10-acre tract.

hours for an efficient crew to put up the gin pole, string the rigging, and get all ready for work at stump pulling. When the stumps are pulled in the first quarter (fig. 15, *A*), the blocks are shifted to the opposite side of the pole and the haulback line strung around the second quarter (fig. 15, *B*). When this quarter has been completed the engine is moved to the opposite side of the pole and the same procedure gone through upon the remaining quarters of the field.

One man places his engine under one of the guy lines, using the same deadman (buried log) for anchoring both the engine and the guy line. Instead of pulling in the quarters *A* and *B* at the beginning, he strings the haulback around one of the quarters *C* or *D* (fig. 15), fastening an extra guy line opposite the point from which he is pulling. While this method saves some time, the extra wear upon the main line is very great, and all the stumps in the quarters *C* and *D* must be extra well blasted so that no very heavy pull will come upon the rigging while in this position. Most operators claim that the extra expense of replacing the main line will more than offset the saving made.

To pull a stump from the field to the pile a choker, or a short piece of cable from 20 to 30 feet in length, with a loop in one end and a choker hook upon the other, is passed around the stump and hooked upon itself, the signal is then passed to the engineer, who starts the engine to winding up the main line, the haulback drum running free and unwinding the haulback line until the load is landed upon the pile around the gin pole. The pile man gives the signal to drop the load when it is in the proper place. He then climbs the pile, unhooks the choker hook, climbs down, and gives the signal for the return of the choker to the hook tender. The empty choker is taken off and a loaded one hooked upon the main line. Sometimes two or three loads are sent in at one time, but as they are liable to become entangled it is the usual practice to send in but a single load at a time.

The signaling is most often done by motioning with the arms. The hook tender usually gives the signals in the field and the pile man at the pile. When for any reason the hook tender is out of sight of the engineer the pile man repeats the signals. Some outfits use a wire attached to the whistle of the engine. This wire is stretched into the fields and near where the hook tender is at work, and a man or boy gives the signals by blasts of the whistle.

The necessity for speed and the irregular size and shape of the material do not permit building a symmetrical or closely packed pile. However, with a good gin pole and a man of some experience a pile can be put up that will burn better than if no attention is given to the piling. The pile should be built as steep as possible (fig. 13), the base extending over the smallest area possible, as a better burn can be made under these conditions.

When the donkey engine is used on contract work it is optional with the contractor how to dispose of the small débris. Some contractors make it up into small loads and haul it to the pile while hauling the larger pieces, thus cleaning up everything as they go. The common method is to pile with the engine everything that two men can not handle easily and to place the small stuff in small piles, which are

burned after the engine work has been done. This method is followed by farmers who have employed the engine and crew to remove the heavier material. By doing their own picking up after the engine has pulled and piled the stumps, they save an outlay of from $10 to $20 per acre.

The cost of clearing land by the donkey-engine method varies widely, even though the work be done upon adjoining tracts of land. If done by different outfits the cost will be quite different, owing to the difference in equipment, management, and efficiency of the crew.

The foregoing description of the manner of operating the donkey engine in clearing land is for the double-drum engine, which is most generally used. However, all sorts of engines have been tried in this work. When the single-drum or traction engine is used the cable is hauled back by a horse or team. Where these engines have been tried the cost has always been high and they were soon abandoned.

IMPROVEMENTS THAT COULD BE MADE IN THE DONKEY-ENGINE OUTFIT.

The engine is the most important as well as the most expensive part of the outfit, and most of the engines in use should be improved or replaced by better ones. An outfit embodying the ideas of an experienced operator is here outlined. An engine designed especially for stump pulling has recently been put upon the market. It is stronger in breaking out stumps at slow speed, but the speed for hauling to the pile is very little faster than the ordinary logging donkey. An engine for clearing purposes should have a larger boiler and should be designed to run at a greater speed in hauling to the pile.

The greatest saving of time, after all losses on account of defective engines have been eliminated, can be effected by the use of a self-releasing choker. Such a choker automatically releases the load upon the pile when the engine is reversed. The large hook upon the main line is drawn back out of the loop upon the end of the choker, while the trip line releases the choker hook and brings it back. A choker of this kind rarely fails to release its load and it never drops it, a thing which often happens when using the old-style choker. Its use makes the pile man unnecessary, thus eliminating that dangerous work. Fully twice as many loads can be put upon the pile by the use of this device as by the use of the old-style choker. It is no heavier and is fully as easy to handle as the old one, being practically the same thing with the addition of the small trip line that is attached to the choker hook at each loading.

Another improvement can be made by using an electric-bell outfit for signaling instead of the whistle wire or the other mode of signaling.

This will be almost a necessity when using a high-speed engine and a self-releasing choker. This outfit should consist of a good clear bell, a strong battery that may be placed in a box above the engine, and lead wires well insulated and made into a cable that can be laid upon the ground to the point where the hook tender and helpers are at work. The signals can be given by one of these men, thus dispensing with an extra man to do this work.

A small saving can be effected by placing spring grease cups upon the blocks of the gin pole. These cups should be large enough to hold a week's supply. It requires 30 minutes each day to send a man up to oil these blocks when cups are not used.

ESTIMATE AND SPECIFICATIONS FOR A DONKEY-ENGINE OUTFIT.

The following specifications for a donkey-engine outfit are given by a man who has had extensive experience as the best to be had for land clearing.

A compound geared yarder, with two speeds to the main drum, giving approximately 100 and 250 feet per minute, with the haulback geared to run at 300 to 350 feet per minute, is required. The cylinders should be 9 by 10 or 10 by 12 feet. The hauling drum should be fitted with a steam friction. The boiler should be extra large. There should be 1,000 feet of 1⅛-inch main line of six strands of 19 wires each and 2,000 feet of ⅝-inch haulback line of six strands of 19 wires each.

Estimate of cost of donkey-engine outfit.

Engine and boiler	$3,500
Main line	200
Haulback line	150
Bull block for gin pole	75
Six self-releasing chokers (¾ inch, ⅞ inch, and 1 inch)	60
Four haulback blocks, hooks, and swivels	70
Four 1-inch guy lines, 250 feet each	150
One lead block for haulback line	35
Electric-signal outfit	10
Tools, extra hooks, blocks, etc	150
Total	4,400

While this outfit is too expensive for small owners, it could be purchased by a community, or one or more such outfits could be operated by a county or a large company for clearing land. It would be more satisfactory than the makeshift outfits usually found doing this work.

COST OF DONKEY-ENGINE WORK.

Table X, compiled from records kept during actual clearing operations, will afford an approximate idea of the cost of clearing land by the use of the donkey engine.

TABLE X.—*Summary of cost of clearing 18 tracts of land.*

Tract No.	Acres.	Stumps.			Explosives.		Cost, including labor.	
		Number.	Average diameter.	Average number per acre.	Cost.	Average cost per acre.	Total.	Average per acre.
			Inches.					
5	11	280	26	26	$199.10	$18.10	$967.05	$87.91
5A	16	381	38.4	24	270.85	16.93	1,317.10	82.32
6	10.2	473	19.1	46	48.65	4.77	494.41	48.47
7	18	331	27	19	213.00	11.83	853.30	47.40
8	5.5	166	36.2	30	83.15	15.11	332.15	60.39
9	7.5	157	36.2	21	135.45	17.95	527.40	70.33
10	5.25	223	35.5	42	124.00	23.63	388.90	74.04
12	11.7	490	29.1	42	170.75	14.59	734.75	62.80
13	13	.....	.....	.....	172.70	13.28	714.45	54.96
14	6.4	358	24	56	72.90	11.40	314.75	49.20
16	4.6	115	38.5	25	75.00	16.30	322.00	70.00
17	5.8	210	37.3	36	63.30	10.91	335.40	57.83
18	16.04	224	37.5	14	229.10	14.27	957.45	59.69
19	5.3	89	52.5	18	68.80	12.98	278.00	52.45
20	6.1	190	35	31	101.95	16.71	541.50	88.77
21	19	552	36.6	29	179.85	9.47	1,395.55	73.45
22A	3.61	194	39.6	53	310.60	86.04	804.55	222.87
22B	3.8	200	40.4	53	258.05	67.94	505.80	133.10

Additional details relating to certain of the tracts contributing data to Table X are here given.

Clearing No. 5A: 16 acres of silt soil with a clay subsoil; water very near the surface. Outfit: 9 by 10¼ inch donkey engine, 800 feet of 1-inch main cable, 1,600 feet of ⅝-inch haulback cable, four 1-inch guy lines, each 150 feet long, gin pole 100 feet high, and tools. The stumps on the entire 16 acres were pulled to one pole, making very long hauls in some places. Half of this tract was very wet while the work was being done, making slow work of the clearing.

TABLE XI.—*Cost of labor and material used in clearing tract No. 5A.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
Engineer	27.8	$3.75	$104.25
Fireman	26	3.00	78.00
Pile man	27	3.00	81.00
Hook tender	27	4.00	108.00
Choker man	27	3.50	94.50
Laborers	84.3	2.50	210.75
Field boss	30	3.00	90.00
Powder man	43.75	3.00	131.25
Hire of horse	20	1.00	20.00
Labor in slashing and burning	.....	.....	128.50
Total cost of labor	.....	.....	1,046.25
Powder (47 boxes, 2,350 pounds), fuse, and caps	.....	.....	270.85
Total	.....	.....	1,317.10
Average per acre	.....	.....	82.32

[1] Time of clearing, Sept. 14 to Oct. 18, 1909.

A great deal of small stuff and 642 logs were to be piled and burned on this tract.

TABLE XII.—*Stumps pulled, tract No. 5A.*

Kind of stumps.	Diameter of stumps (inches).																Number of stumps.
	6	8	12	18	24	30	36	42	48	60	66	72	78	84	96	Average.	
Cedar	....	....	3	8	29	31	31	28	31	30	3	6	5	1	4	38.4	210
Fir	....	....	....	....	1	2	3	2	5	2	....	....	1	....	....		16
Hemlock	....	2	....	12	11	2	3	....	1	....	....	....	....	....	....		31
Spruce	....	....	1	11	18	22	28	—9	13	7	....	1	....	....	....		110
Alder	4	....	7	....	1	....	....	....	....	....	....	....	....	....	....		12
Cottonwood	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....		1
Total	4	2	12	31	60	57	65	39	51	39	3	7	6	1	4	.....	381

The average number of stumps per acre was 24. It required two days and six hours to move from tract No. 5 to this tract and put up rigging ready for work. Time lost owing to breakdowns and mismanagement, 30 hours. Weather conditions fair; two days' time lost on account of rain. The small logs and other débris were made into small piles and burned where piled.

Clearing No. 7: 18 acres of low ground having a sandy loam soil and a loose, sandy subsoil. Outfit: 10 by 12 inch donkey engine, 1,000 feet of 1-inch main cable, about 5,000 feet of $\frac{5}{8}$-inch haulback cable, four 1-inch guy lines, each 150 feet long, one 10-inch pole block, four 8-inch haulback blocks, an 80-foot gin pole, and tools. This tract has been in pasture for a number of years. The grass having run out, it was decided to take out the stumps and use the land for farm crops. The slashing and burning had been done at some previous time at a cost of about $30 per acre.

TABLE XIII.—*Cost of labor and material used in clearing tract No. 7.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
Engineer	13.8	$3.50	$48.30
Fireman	12.3	2.00	22.60
Pile man	12.3	3.25	39.95
Hook tender	12.3	3.50	43.05
Choker man	12.3	2.50	30.75
Powder man	12.3	3.25	39.95
Do	8.3	2.75	22.75
Man and team	9	5.00	45.00
Laborer	8	2.50	20.00
Hire of engine	11.3	11.50	129.95
Owner's work	10	2.50	25.00
Labor in picking up and burning after donkey engine			150.00
Repairs to rigging			23.00
Total cost of labor			640.30
Powder (42 boxes, 2,100 pounds)			208.00
Fuse and caps			5.00
Total			853.30
Average per acre			47.40

[1] Time of clearing, Aug. 6 to Aug. 19, 1909.

Some small logs and 108 large ones were to be piled and burned on this tract, most of the small logs having been burned previously.

TABLE XIV.—*Stumps pulled, tract No. 7.*

Kind of stumps.	Diameter of stumps (inches).										Number of stumps.
	12	18	24	30	36	42	48	60	72	Average.	
Cedar	....	....	4	....	....	....	3	....	3	27	10
Cottonwood	4	5	1	11	18	9	25	20	3		96
Alder	51	50	27	8	1	....	....	....	....		137
Spruce	....	....	1	2	5	....	7	2	....		17
Fir	....	....	....	....	2	4	....	....	....		6
Crab apple	45	20	....	....	....	....	....	....	....		65
Total	100	75	33	21	26	13	35	22	6	.....	331

The average number of stumps per acre was 19. It required two days and five hours to move to this tract and get rigging into shape to pull the stumps. Eighteen hours were lost in moving rigging in the field and owing to breakage. The small logs and trash were hauled upon a sled to the pile to finish burning it.

Clearing No. 12: 11.7 acres of valley land, having a silt soil and a clay subsoil. Outfit: 9¼ by 10 inch donkey engine, 800 feet of 1-inch main cable, 1,500 feet of ⅝-inch haulback cable, four 1-inch guy lines, each 180 feet long, gin pole, and tools. This tract was in the form of a square and only one gin pole was necessary, the maximum haul being little more than 500 feet.

TABLE XV.—*Cost of labor and material used in clearing tract No. 12.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
Donkey engine and 5 men	12.1	$25.00	$302.50
Powder man	20	2.00	40.00
Labor in picking up and burning after donkey engine	.....	.....	165.00
Total labor expense	.....	.....	507.50
Powder (29½ boxes, 1,475 pounds), at 11 cents per pound	.....	.....	162.25
Fuse and caps	.....	.....	8.50
Board of men	.....	.....	56.50
Total	.....	.....	734.75
Average per acre	.....	.....	62.80

[1] Time of clearing, Oct. 6 to Oct. 30, 1909.

One week was lost in repairing engine. One day and three hours were required to move to this tract, raise the gin pole, and get ready for pulling stumps.

Many small logs and 185 large ones were to be piled and burned on this tract. Slashing had been done some years before.

TABLE XVI.—*Stumps pulled, tract No. 12.*

Kind of stumps.	Diameter of stumps (inches).									Number of stumps.
	12	18	24	30	36	42	48	60	Average.	
Cedar	20	35	50	60	58	35	32	20	29.14	310
Fir	....	....	....	6	....	5	1	....		12
Cottonwood	....	....	1	4	2	4	4	1		16
Spruce	3	11	18	19	25	15	5	6		102
Alder	31	5	....	....	....	....	....	....		36
Maple	12	1	1	....	....	....	....	....		14
Total	66	52	70	89	85	59	42	27	.....	490

The average number of stumps per acre was 42. The trash and the small logs that were not piled by the donkey engine were gathered into small piles and burned after the other work had been done.

Clearing No. 20: 6.1 acres of valley land, having a silt soil and a clay subsoil. Outfit: 9¼ by 10 inch donkey engine, 800 feet of 1-inch main cable, 1,600 feet of ½-inch haulback cable, blocks, guy lines, and tools.

TABLE XVII.—*Cost of labor and material used in clearing tract No. 20.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
Engineer and hook tender	11.15	$16.00	$178.40
Fireman	11.15	2.00	22.30
Pile man	11.15	3.00	33.45
Choker man	11.15	2.00	22.30
Powder man	13	3.00	39.00
Team and teamster	4	5.00	20.00
Labor in picking up and burning after donkey engine	.....	.....	79.10
Total	.....	.....	394.55
Powder (18 boxes, 900 pounds)	.....	.....	99.00
Fuse and caps	.....	.....	2.95
Board of men	.....	.....	45.00
Total	.....	.....	541.50
Average per acre	.....	.....	88.77

[1] Time of clearing, Dec. 21, 1909, to Jan. 22, 1910.

There were 155 large logs upon this tract to be piled with the stumps around the gin pole. The slashing and burning had been done some time before, but a large amount of small trash and logs had to be picked up after the engine work was done. Two gin poles were used upon this tract. It required 2½ days to set up the gin poles, change the rigging, and get ready for pulling stumps.

TABLE XVIII.—*Stumps pulled, tract No. 20.*

Kind of stumps.	Diameter of stumps (inches).													Number of stumps.
	12	18	24	30	36	42	48	60	72	84	96	132	Average.	
Cedar	9	9	7	5	17	1	16	12	18	1	1	1	35	97
Alder	16	17	....	....	....	....	....	....	....	....	....	....		33
Spruce	2	16	5	12	14	....	4	4	1	2	....	....		60
Total	27	42	12	17	31	1	20	16	19	3	1	1	.....	190

The average number of stumps per acre was 31. Two weeks were lost on account of the ground being frozen. Only two hours were lost on account of breakage. The small logs and trash were piled and burned after the engine had finished piling the stumps and large logs.

Clearing No. 22A: 3.61 acres of high land, having a sandy loam soil and a sandy, gravelly subsoil. This tract had been logged off four years before and had been burned over twice since that time. The snags and dead trees were either cut down or blasted without cutting. The latter proving to be the cheaper method. Outfit: 10 by 12 inch donkey engine, 800 feet of $1\frac{1}{8}$-inch main cable, 1,500 feet of $\frac{5}{8}$-inch haulback cable, blocks, guy lines, and tools.

TABLE XIX.—*Cost of labor and material used in clearing tract No. 22A.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
Engineer	21	$3.00	$63.00
Fireman	21	2.50	52.50
Wood sawyer	16	2.50	40.00
Hook tender	21.4	4.00	85.60
Choker men and pile man	58.6	2.50	146.50
Choker man	9	2.75	24.75
Powder man	14.5	3.25	47.10
Powder man	11.5	3.00	34.50
Total labor expense			493.95
Powder, (63 boxes, 3,250 pounds), at 9.7 cents per pound			305.55
Fuse and caps			5.05
Total			804.55
Average per acre			222.87

[1] Time of clearing, Mar. 8 to Apr. 12, 1910.

Some of this tract had been logged off by hand and burned previous to this clearing. The remainder had a large number of large logs to be piled with the stumps around the gin pole.

TABLE XX.—*Stumps pulled, tract No. 20A.*

Kind of stumps.	Diameter of stumps (inches).											Number of stumps.
	18	24	30	36	42	48	54	60	66	72	Average.	
Cedar	....	2	7	5	11	3	....	2	....	....	39.6	30
Fir	6	14	9	13	35	24	19	7	3	2		132
Hemlock	4	8	7	6	4	1	1	....	....	....		31
Maple	1	....	....	....	....	....	....	....	....	....		1
Total	11	24	23	24	50	28	20	9	3	2	.....	194

The average number of stumps per acre was 53. The high cost of the work upon this tract is due to excessive use of powder; poor engine, blocks, and lines; inexperienced crew; and bad weather.

The cost of handling the rigging in this work was $110.70. The loss in delays owing to poor rigging cost $46.70.

Clearing No. 22B: 3.8 acres of high land, having a sandy loam soil and a sandy, gravelly subsoil. This tract is adjacent to tract 22A and is similar to it in every respect. Outfit: Same as that used on tract No. 22A.

TABLE XXI.—*Cost of labor and material used in clearing tract No. 22B.*[1]

Item.	Days employed.	Cost.	
		Per diem.	Total.
Crew:			
Engineer	10	$3.00	$30.00
Fireman	10	2.50	25.00
Wood sawer	10	2.50	25.00
Hook tender	10	4.00	40.00
Choker man	12	2.50	30.00
Choker man	5	2.75	13.75
Signal man	6	2.50	15.00
Powder man	12	3.25	39.00
Powder man	10	3.00	30.00
Total labor			247.75
Powder (52 boxes, 2,600 pounds), at 9.7 cents per pound			252.20
Fuse and caps			5.85
Total			505.80
Average per acre			133.10

[1] Time of clearing, Apr. 13 to 23, 1910.

A part of tract 22B had been logged off and burned by hand previous to this clearing. The remaining part had a large quantity of logs and trash upon it to be piled with the stumps around the gin pole. The self-releasing choker was used upon this tract, and to this is due a part of the reduced cost of the clearing. Less powder was used in this work than upon the adjacent tract, but the stumps were well shot and very few required to be shot the second time. It is possible that still less powder could have been used with equally as good results.

TABLE XXII.—*Stumps pulled, tract No. 22B.*

Kind of stumps.	Diameter of stumps (inches).										Average.	Number of stumps.
	18	24	30	36	42	48	54	60	69	84		
Cedar	1	8	8	5	7	3	....	2	....	....	40.4	34
Fir	3	10	24	20	33	30	25	10	1	1		157
Hemlock	1	1	6	....	....	....	1	....	....	....		9
Total	5	19	38	25	40	33	26	12	1	1	.....	200

The average number of stumps per acre was 53. It required 1 day and 6 hours to move the outfit and put up the rigging ready for work. Ten hours were lost owing to poor rigging and inexperienced help.

GASOLINE ENGINES FOR STUMP PULLING.

A few gasoline engines of small power have been tried in stump pulling upon small tracts. They are generally so arranged that the engines run continuously, while the drums are started or stopped by means of a clutch or similar device. In the gearing of these small engines speed is sacrificed to power. This makes them very slow, the load traveling to the pile much more slowly than a man can walk. There being no change of speed, no long hauls are made. The stumps must be very well split and loosened for such an outfit, and the piles are necessarily small. Two men can handle an outfit of this kind. Two men, with a good team, blocks, and line, can do fully as much as one of these outfits and at about the same cost.

METHODS OF BURNING.

About the first method used by the early settler in destroying stumps was to bore intersecting holes into the stump and, by the use of oil, pitch splinter, or hardwood coals, start a fire at the intersection of these auger holes. By careful manipulation of these fires he was able to burn the top and the crown of the stump and separate the large roots, which were afterwards removed by the use of a team and blocks or a stump puller. This method is very rarely used at the present time. Another method employed by the early settler and used in some localities at this time is to split the stump by a small charge of powder, after which it is set on fire and kept burning by piling into the cracks small logs, brush, and other stuff that is picked off the ground. After the burning has done all it will the remaining roots are pulled by team or a stump puller.

As early as the year 1870 a patent was granted upon a stump burner that consisted of a hood of sheet iron to set over the stump. Since that time several similar contrivances have been patented, none of which are in use to-day upon the fir stumps of Washington. Where tried, they have only succeeded in burning the stump off at the surface of the ground, leaving the roots in the soil. Another objection to the use of the hood upon the fir stumps is the great size of hood required to cover the large stumps.

USE OF CHEMICALS IN THE DESTRUCTION OF STUMPS.

For some years past formulas for the destruction of stumps by the use of chemicals have appeared from time to time in various publications. It has been claimed that by treating a stump with saltpeter or a mixture of sulphuric and nitric acids it could be burned out completely to the tips of the smallest roots. The method was to bore an auger hole into the stump, fill it with the mixture, and allow it to stand for several months, after which it was to be covered with coal oil and set on fire. Both these methods have been tried with no success whatever.

NEW METHODS OF BURNING STUMPS.

THE BLOWING MACHINE.

The blowing machine usually consists of a gasoline engine, a blower, a distributor, and several lengths of rubber hose with short lengths of iron pipe upon one end. (Figs. 16 and 17.) Some of the machines use tin conductor pipes, connected by short pieces of rubber hose instead of the long lengths, as the former are cheaper. Usually one or more patented devices are in use about each of these machines. The air from the blower is divided into an equal number of parts by the distributor and forced through the sections of hose to the nozzle, from which it is directed upon the fire.

One method of operating is to bore holes with a 1¼-inch auger into

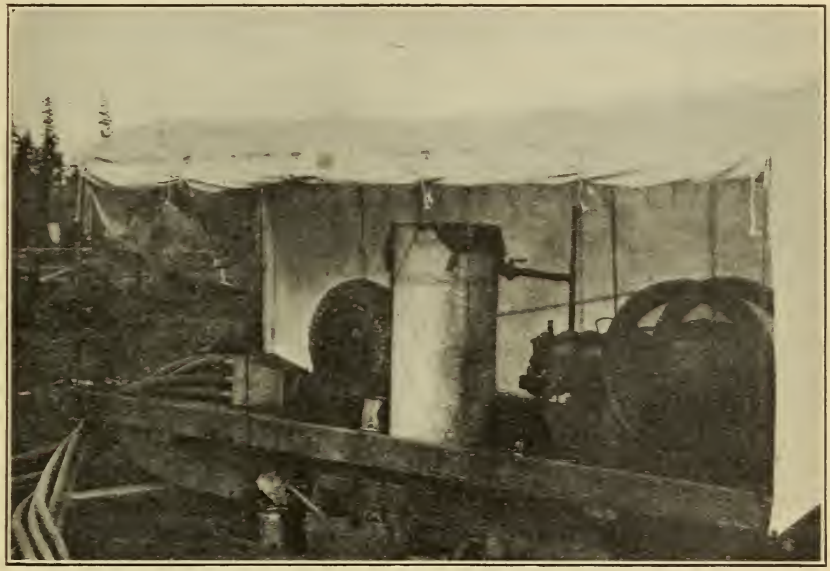

FIG. 16.—A blowing-machine outfit for burning stumps.

the roots of the stumps at a sufficient depth below the surface to permit of plowing, the earth having first been removed from around the stump to a depth of from 12 to 18 inches. A fire is started at the bottom of the holes by means of a hot iron, the nozzles being placed at the openings. The air blasts keep the fire going. While these are burning, four holes are bored 2 or 3 feet above the first ones, so that they would intersect if bored deep enough. Fires are started in them in the same manner. After these holes burn to an intersection they will continue burning after the air blasts are removed.

Another method of operating the blowing machine is to chop a notch into the stump at several points and to roll short logs against

it at these points, start fires between the logs and stump, and direct the air blasts upon the fires. The destruction of the stump by this method does not take place as quickly as is popularly supposed or as quickly as is claimed by the inventors of the processes. While a great heat is generated, it seems impossible to hasten the burning beyond a certain point. As most of the stumps to be burned are quite old and contain a large quantity of water, even in the summer months, the best results are obtained when using this machine by operating it continuously day and night until the stumps fired at one time are completely consumed. One man can operate a machine

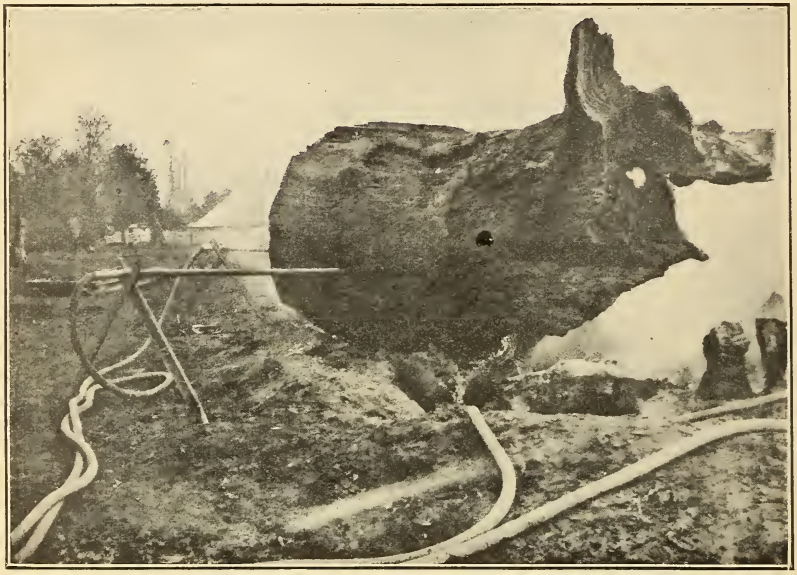

FIG. 17.—A stump showing the work of a blowing machine.

of this kind where only 5 or 6 lines of hose are used. Where 12 or 14 lines are used 2 men are required most of the time.

Although several of these machines have been sold throughout the country, very few have been operated successfully or have met the requirements of the purchasers. As a result, most of them have been abandoned. The principal objection to this method of removing stumps is the difficulty of burning the roots far enough below the surface to admit of cultivation. This can be done where the stumps root deeply or on clay soil.

These outfits cost from $350 to $500 complete. The cost of gasoline and lubricating oil to operate the outfit is approximately $1 per day of 10 hours.

COST OF USING THE BLOWING MACHINE.

Clearing No. 23: Three-quarter acre tract; had been used for pasture; slashing and burning had been done two years before. The soil was a loose, sandy loam. Outfit: 4½-horsepower gasoline engine, blower, air distributor, 12 lengths of 2-inch rubber suction hose with 8-foot nozzles, 12 lengths of ¾-inch rubber hose with ½-inch pipe; nozzles, augers, tools, etc.; cost of outfit, $500. The crew consisted of two men.

Size and number of stumps (all fir): 24-inch, 1; 54-inch, 1; 60-inch, 5; 72-inch, 1. Total number on three-fourths acre, 8; average diameter, 56¼ inches.

Cost of labor, 115¼ hours, at 25 cents per hour, $57.75; gasoline and lubricating oil, $10.80; total, $68.55. Cost per acre, $91.40.

While this cost is high, the actual cash outlay is only $10.80 for three-fourths of an acre, or $14.40 per acre, the labor being furnished by the owner of the land.

The stumps were deeply rooted and were easily burned below the depth that the soil would be plowed. No roots were found running along the surface of the ground.

CHAR-PITTING.

The method of char-pitting stumps, also known as charcoaling, has been used, usually in a small way, for 20 to 30 years in the States of Washington, Oregon, and Idaho. It has been known and used for a period of 20 years in the State of Washington in localities where clay soils are found, but small tracts only have been cleared by its use. Until recent years it has not been generally known, and where known but little practiced. One field of 16 acres was found which had been cleared of 603 large fir stumps by this method. This is the largest tract cleared in this way in recent years. In Oregon tracts of 40, 60, and 80 acres were cleared by this method some years ago.

A clay soil, or a soil containing a considerable percentage of clay, is essential for the best results with this method. Soil that contains clay bakes when used as a covering for the fire about the stump, while sandy soil breaks up and runs, putting out the fire. All the districts in which this method has been used successfully have a clay soil. This method can be used upon fir stumps after they have been cut one year or more. A green stump can not be satisfactorily burned out the same year it is cut. Cedar stumps can not be burned out as well as fir, owing to the fact that they contain no pitch. Also the roots of cedar stumps are nearly always wet, rendering the fire liable to go out and leave a mass of unburned roots.

DETAILS OF THE METHOD OF CHAR-PITTING.

The stumps to be burned should have the bark removed in winter, spring, or early summer, in order that the outside may dry out as thoroughly as possible. A stump with the bark removed is shown in figure 18. The bark need not be removed except at the ground and for a foot or more above ground. The stumps burn best during the late summer or early fall, after the surface wood has become dry. No digging need be done where there is a clay soil.

The kindling is prepared and placed around the stump, as in figure 19. In dry weather, which is the best time for this work, it is very easy to get kindling upon new ground, as the rotten wood and

FIG. 18.—A stump, with the bark removed, ready for char-pitting.

small sticks serve the purposes as well as the best of sound wood. The wood is either stood on end, as in figure 19, or laid compactly about the stump. The smaller kindling is placed next the stump. If ferns, grass, or small leafy bushes are to be had near by, it is well to cover the top of the kindling with them to prevent the fine part of the earth covering from sifting in among the wood (fig. 20). The earth covering can now be placed upon the ferns (fig. 21).

The kindling is covered by beginning at the bottom. The shovelfuls of earth are laid on carefully so as to prevent breaking, loosely to give draft, and in coarse chunks to prevent the covering from falling in. The whole of the kindling is covered, except a small opening at which to light the fire, as shown in figure 21. The earth should be

FIG. 19.—Char-pitting. Kindling in place around the stump.

FIG. 20.—Char-pitting. Kindling covered with ferns to prevent the fine, loose earth from sifting into it.

laid upon the kindling to a depth of 2 or 3 inches. The layer of earth should meet the stump snugly, so as to leave no air holes. After the fire is started, it is allowed to burn for 30 minutes or more, when the small opening is closed by a shovelful of clay. While the kindling is burning, any opening in the covering caused by the burning out of the wood underneath should be closed by a shovelful of new earth. Covering too deeply should be avoided. As the stump is burned away, the hot clay is pushed over the fire and new clay added as required.

Stumps require more attention directly after they are fired than at any other time during the operation. If not taken care of at this

FIG. 21.—Char-pitting. Earth covering in place. Opening left at which to light the fire.

time the fire is likely to go out. Stumps that have the necessary attention for the first two or three days after the fire is started do not require to be looked after more than twice a day thereafter. They should be looked after until the last root has burned below the plow depth. One man can prepare for burning from 10 to 20 stumps per day, depending upon the size of the stumps and the supply of kindling. Where it is necessary to cut wood and haul it to the stumps, as, for instance, when working in a meadow in which everything except the large stumps have been removed, 16-inch wood will be found to be most convenient, but longer wood may be used upon the larger stumps. It is best to fire the stumps at such time that they

may be looked after several times before leaving them for the night. It is a good plan to fire the previous half day's work when beginning work in the morning and afternoon. By doing this the stumps may be given frequent attention before being left for the night. They should be looked after the first thing in the morning.

A bucketful of ashes saturated with coal oil makes a handy means of starting fires. A handful of these ashes placed among the kindling in the opening will readily catch fire and start the wood burning, thus dispensing with the need of providing shavings or pitch for each fire. One man can look after and keep several hundred stumps going after they have been well started. In favorable soils, if well cared for, this method will burn out most of the roots far below the depth of cultivation. Some of the roots will not burn, but there will be fewer of these than are left by any other method employed at this time for clearing land. Much labor and time can be saved in char-pitting if the stumps that catch fire when the slashing is burned are covered at that time. Many of these will need no further kindling. Upon one tract several stumps were burned out by covering them after they were fired by a running fire in the grass about them.

ANOTHER METHOD OF CHAR-PITTING.

A slightly different method of char-pitting has been successfully used near Little Falls, Wash. In this work a shallow excavation is made between two large roots close to the stump in the spring when the ground is soft, and the bark is removed from these roots at that time. In the summer, after the hay crop has been taken care of, sound fir wood is cut into 16-inch lengths, hauled to the meadow, and distributed, allowing enough, when split, to make a large armful of wood to each stump. This wood, with kindling to start the fire, is placed in the hole between the large roots and fired. When the fire is well started it is covered over. As the stumps burn, new covering is added each day to keep the fire inclosed. A stump that has been burning five days is shown in figure 22, the clay covering reaching halfway around the stump. In figure 23 a stump is seen where the banking has been completed, the fire having burned entirely around it. This illustration also shows that this method can be used very near a building in the driest weather with the minimum amount of danger if the fire is kept well banked at all times.

Old snags and dead standing trees are as readily treated by this method as short stumps, and it costs no more to burn their roots than those of ordinary stumps. When the stumps have fallen over, it is necessary to keep the roots covered, care being taken not to smother the fire by putting on too much earth. If the stump is kept well banked at all times before it burns off it will not need additional

covering to burn out the roots, but it must not be allowed to cave, leaving the roots exposed, or the heat will be lost and the roots will

FIG. 22.—A stump that has been burning five days. The clay covering has reached half way around the stump.

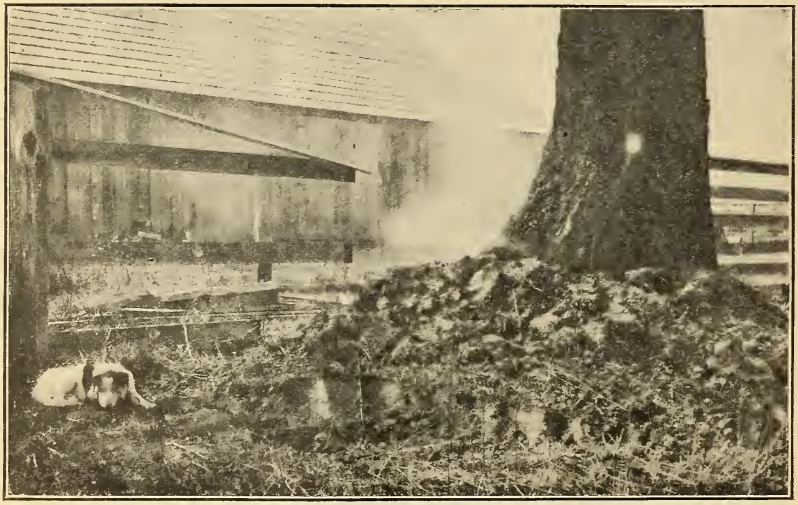

FIG. 23.—A stump around which the banking has been completed. This stump is burning near a barn during the driest season of the year with very little danger to the building.

not burn. If the fire is allowed to go out before the roots are burned well below plow depth, it is more trouble to get the fire started again

than it was to start the fire in the first place. In such cases it is often cheaper to grub or pull out the roots.

This method requires less kindling than that of encircling the stump with fire at the beginning. This is an important item when the kindling must be cut and hauled to the stumps. More stumps can be fired in a day than where the stump is encircled by the kindling, but the labor is about the same in both methods. There is no difference in the efficiency of the two methods, other conditions being equal.

The tools needed in the work are the same in both cases. A mattock for removing the bark, an ax for cutting and splitting the

FIG. 24.—Tools used in char-pitting.

kindling, and a shovel for covering the wood (fig. 24). A crosscut saw is essential where the kindling must be cut from large logs.

CHAR-PITTING IN SOILS OTHER THAN CLAY.

While stumps have been successfully and cheaply destroyed by char-pitting in localities where the soil is largely composed of clay, no one has yet been able to use this method successfully where the soil is sandy or gravelly. Many experiments have been carried on to adapt this method to these unfavorable conditions. The results of these experiments are given below. It was found that the soil in which the stump stood could not be used to cover the kindling and bank the stump, as the sand and gravelly soil broke down under the

action of the heat, extinguishing the fire. By hauling clay or cinders with which to cover the kindling and bank the stump it was found to be an easy matter to burn off the stump at the surface of the ground. In no case where this was tried did the roots burn below the surface far enough to permit of plowing. It was found that by digging a trench around the stump the fire would follow as deep as the trench had been dug.

Where the roots do not go directly into the soil for some distance, it would be of small advantage to burn the stumps in this manner. The fire will follow the roots only a short distance into the sandy soil. Stumps and roots that have been left under the surface are very expensive to remove, as it is nearly always necessary to dig them out by hand. When the land is simply to be left in grass there is some advantage even in burning stumps to the level of the ground. But if the land is to be devoted to cultivated crops the roots thus left in the soil are a serious hindrance.

The best covering to use when char-pitting in sandy soil is clay, but cinders may be used. The original soil must be removed to the depth to which it is desired to burn the roots. In sections where the stumps are shallow rooted in sandy and gravelly soil, char-pitting has not been used effectively. In cases where there is any doubt of the effectiveness of this method, test stumps should be fired and carefully tended. This will give, with very little expense, an idea of how the method works upon the soil in question before any extensive work is attempted.

FUEL OIL IN CHAR-PITTING.

There are very few stumps that can not be fired without the use of oil or material other than ordinary kindling during July and August. If it is desired to char-pit during the winter, when the stumps and kindling are both wet, it is well to use oil to start the fire quickly and to make as great a heat as possible at the beginning. The fire may be started by pouring about a gallon of oil upon the kindling piled between two large roots of the stump. During wet weather this method of starting the fire is usually as good as, if not better than, that of placing the kindling entirely around the stump and using several gallons of oil. However, it is poor policy to use any of the char-pitting methods during the wet season, as the expense is more than doubled and the results are not nearly so satisfactory. Some stumps can not be made to burn, others require to be fired several times, and none of them burn as well as in the summer months. The roots are very liable to quit burning before they are out of reach of the plow. Figure 25 shows the results of char-pitting a stump in sandy soil during the wet season. This stump was fired by the use of

2 gallons of fuel oil. It was banked with coal cinders. The figure shows that the roots were left unburned.

EFFECT OF CHAR-PITTING UPON THE SOIL.

It is claimed by parties interested in other methods of removing stumps that the char-pitting process is more injurious to the soil than other methods of clearing, on account of the burning of the vegetable elements. In char-pitting only the soil used in covering the fuel and that immediately in contact with the roots is affected by the fire. The soil close to large fir stumps contains very little vegetable matter.

FIG. 25.—Roots left in the ground after a test stump had ceased to burn in a sandy soil. This has been advertised as a successful demonstration of char-pitting.

Those who have used this method most assert that less injury is done the soil than where the subsoil is scattered over the surface by blasting.

COST OF CHAR-PITTING.

Clearing No. 25: 5 acres of meadow land; Booth ranch, Lewis County, Wash. Stumps cut 20 to 30 years previously; large fir stumps, quite deeply rooted, generally speaking, although an occasional root would follow close under the surface of the ground; clay soil. The outfit consisted of shovel, mattock, and ax. No special tools were used. Each stump was fired between two large roots, as already described. The work was done in August and September. No rain fell during

this time to interfere with the burning. Size and number of the stumps (all fir): 12-inch, 3; 18-inch, 10; 24-inch, 16; 30-inch, 18; 36-inch, 17; 42-inch, 32; 48-inch, 19; 60-inch, 8; 72-inch, 3; 84-inch, 1. Total, 127; average diameter, 37½ inches. Average number per acre (about), 25.

Labor cost of clearing tract No. 25.

Cutting kindling and preparing and firing stumps, 15½ days, at $2.50	$38.75
Hauling kindling, one-fourth day, at $3	.75
Keeping up fires, 10½ days, at $2.50	23.75
Total	63.25
Average cost per stump	.50
Average cost per acre	12.50

The unburned tops of the stumps were removed at a cost of $15. The value of this method lies in the fact that the work may be done by the owner, with no such outlay of capital as is required where explosives are used. On this tract all the roots of the stumps were removed below the depth for plowing. The method proved to be highly efficient. This land, cleared as it is to-day, represents an outlay of $50 to $75 per acre. The work done previously—slashing, piling, burning, and removing the small stumps—would easily bring the cost up to that amount.

Clearing No. 26: 2 acres of hill land, with red clay soil; Dupertuis ranch, Lewis County, Wash. The land had been slashed, burned over, and used for pasture for several years. Many large logs were still on the ground. The outfit consisted of shovel, mattock, and ax. No special tools were used. The work was done in September and October, 1910. There was no rain to interfere with the burning. Kindling was found upon the ground near by. The stumps were fired by encircling them with a ring of kindling as already described.

Size and number of stumps (all fir): 12-inch, 6; 18-inch, 15; 24-inch, 16; 30-inch, 29; 36-inch, 19; 42-inch, 11; 48-inch, 3; 60-inch, 1. Total, 100, 95 of which were destroyed; average diameter, 30 inches.

TABLE XXIII.—*Cost of labor in stumping and estimated cost of earlier work in clearing tract No. 26.*

Item.	Slashing.	Piling and burning.	Stumping.	Total.
Preparing kindling and firing stumps, 9 days, at $2.50			$22.50	
Caring for stumps, 8 days, at $2.50			20.00	
Total			42.50	
Average cost per stump			.45	
Average cost per acre	$15.00	$20.00	21.25	$56.25

Five stumps did not burn entirely out, owing to lack of attention. Five green standing trees were not taken out.

Clearing No. 27: Tract had been slashed and burned over; part clay and part sandy soil; stumps mostly fir; Crow ranch, Pierce County, Wash. Work done in January, 1911. Weather conditions very bad; snow and rain interfered greatly with the work. Outfit the same as that used on tract No. 26.

TABLE XXIV.—*Stumps destroyed or partly destroyed by char-pitting, tract No. 27.*[1]

Kind of stump.	Diameter of stumps (inches).							Number of stumps.
	24	30	36	42	48	60	Average.	
Fir	4	16	10	6	1	2	34½	39
Cedar	1	1	....	....	....	....		2
Hemlock	....	1	....	....	....	....		1
Total	5	18	10	6	1	2	.....	42

[1] Of 42 stumps fired, 30 were only partly burned below the surface, leaving many roots too near the surface for plowing.

Labor cost of clearing tract No. 27.

Two men and team hauling supplies, 5 hours	$3.25
Preparing stumps, 8 days, at $2.50	20.00
Caring for stumps, 14 days, at $2.50	35.00
Fuel oil, 195 gallons, at 6½ cents	12.70
Total	70.95
Average cost per stump	2.36

The record of tract No. 27 demonstrates that in western Washington, where the winters are wet and the summers dry, the work of clearing can not be done to advantage during the winter months; too much time is lost in refiring the stumps that go out, many refuse to burn altogether, and a much longer time is required to burn them out. In the sandy part of the soil, clay was hauled to cover the kindling at some of the stumps and cinders were used at others. Those covered with clay burned better than those covered with cinders, as the clay shed water and snow better. The roots of the stumps in sandy soil burned some distance below the surface of the ground, but not so far as those in clay soil.

CONCLUSION.

It will be seen from the foregoing data that a man without capital can not hope to clear, in a short time, a large enough tract of land upon which to support a family. Under the most favorable conditions and with the lightest clearing ground the cheapest rate at which logged-off land can be prepared for the plow is $50 per acre. The maximum should not ordinarily exceed $150 per acre, although

there are exceptional tracts that will cost $200 per acre to clear. This shows that it is no small undertaking to make a farm out of this land and that it is not feasible for the poor man unless he has other employment to provide sustenance for himself and family while the clearing is in progress. It is the opinion of all who have carefully studied this problem that work of this kind ought to be done on a large scale, at a small profit, for the public good. Possibly the aid of the State will be required before these wastes are made into agricultural land.

The donkey-engine method of clearing is a very efficient and serviceable one. Where it is well equipped and properly managed the expense need not be prohibitive. Extra expense in most instances is due to poor equipment, lack of experience, and bad management. Most of the clearing that is being done at this time is by the donkey-engine method.

Donkey-engine outfits could be purchased by the county or community. By employing one or two experienced men the other work could be done by the owners of the land to be cleared. In this manner the expense could be kept down to a minimum. A donkey-engine outfit could be used to advantage in connection with the char-pitting method to pile the burned-off tops of the stumps, logs, and débris when the work is done on a large scale.

Powder plays an important part in the clearing of logged-off land, as a powerful agent is required to dislodge large stumps. All of the devices for pulling large stumps are dependent on powder to split and loosen the stump before it is pulled. A cheap explosive would be an incentive toward clearing land.

The blowing machine and other devices for the destruction of stumps, while yet in the experimental stage and by no means perfect, may develop into cheap and efficient methods of clearing land.

Wherever the char-pitting method can be used successfully it should be employed, as it is the simplest, cheapest, and most efficient of all methods of clearing land where the conditions are favorable. In unfavorable soil it is liable to leave too many unburned roots in the ground. Surface clearing, as the method which leaves the roots under the surface is called, is the worst form of clearing possible. Many purchasers of cleared land after paying a large price have found that only the surface had been cleared and that the land could not be cultivated until the roots were removed. Experienced men would rather have the stumps where they can be seen than have them cut off and covered up.

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